RTCA SC- 186/WG-6 (Working Group On DO-242A MASPS)

Meeting #8, Washington DC

Draft Text for DO-242A
TCP Terminology

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SUMMARY
This paper offers draft text for introducing the terms "Trajectory Change Point (TCP)" and "Trajectory Change Report (TCR)."

2.2.3.2.1 Trajectory Change Intent (Current and Future)

Track extrapolations based on the use of intent data alone are increasingly inaccurate as look-ahead times are increased. The state vector can be augmented with trajectory change points (i.e., intent information) for applications on the receiving A/V or ATS to:

a) support stable separation predictions for long look-ahead times, and in monitoring required operational separations and

b) re-plan flight paths when necessary to resolve detected conflicts (deconfliction) while minimizing deviations from planned flight trajectories.

The ADS-B system shall (R2.30) provide the capability to exchange Trajectory Change Point (TCP) and Trajectory Change Point + 1 (TCP+1) data defined below. ADS-B transmissions shall (r2.31) indicate the ability of the transmitting participant to engage in path monitoring and/or de-confliction operations. The transmitting A/V shall (R2.32) also indicate its capability to use intent information received from other participants.

For certain pairwise operations, an addressed crosslink may be used external to the ADS-B system.

2.2.3.2.1.1 ~~Current Trajectory Change Point (TCP)~~TCP and TCR Concepts

The ~~*TCP*~~ ***Current Trajectory Change Point*** (TCP+0) from the transmitting aircraft is defined as the point in three-dimensional space where the current operational trajectory is planned to change. Likewise, subsequent Trajectory Change Points (TCP+1, TCP+2, and TCP) are points in three-dimensional space where the aircraft's trajectory is planned to change at later times. The term "TCP" is used in this document to mean either the current trajectory change point (TCP+0) or trajectory change points in general (TCP+0, TCP+1, TCP+2, or TCP+3).

Each trajectory change point (TCP+0, TCP+1, TCP+2, TCP+3) is described in a ***Trajectory Change Report (TCR)***. The TCR *may* describe the TCP as a unique point in three dimensional space (latitude, longitude, and altitude). More generally, however, the TCR lists conditions which, when satisfied, cause equipment on board the transmitting aircraft to recognize that it has reached the TCP.

Figures 2.2.3.2.1.1-A, -B, and -C illustrate several ways in which TCPs might be described in TCRs. In Figure 2.2.3.2.1.1-A, The TCR specifies the TCP's latitude, longitude, and altitude, thereby defining the TCP as a particular point in three-dimensional space.

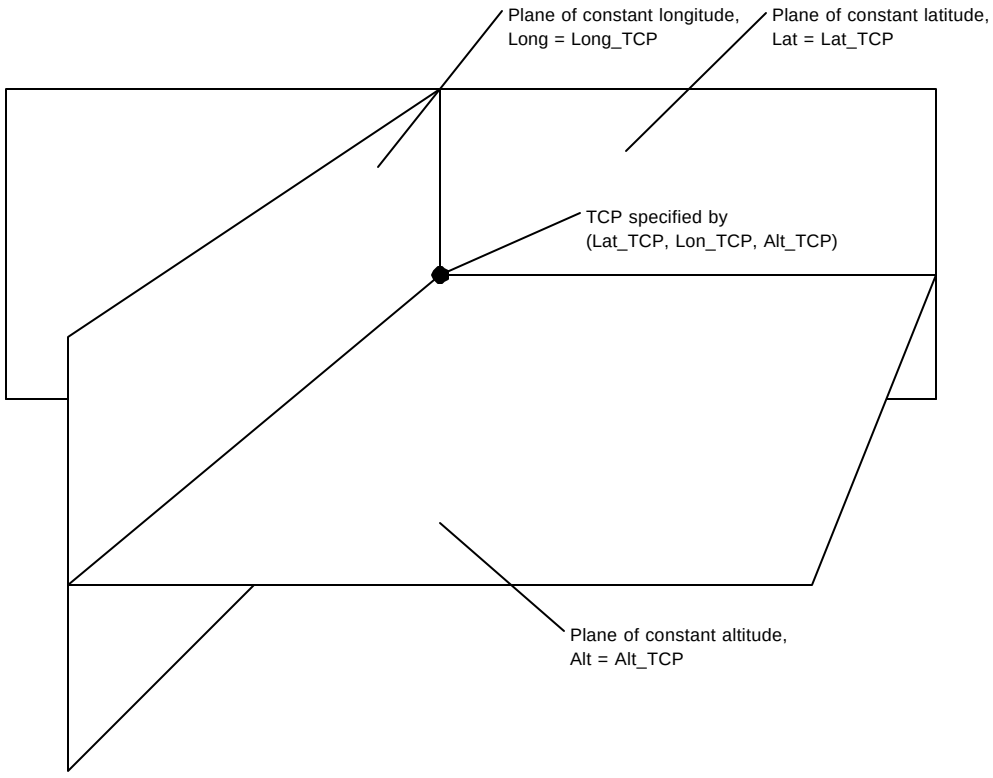

Figure 2.2.3.2.1.1-A: TCP Defined by Latitude, Longitude, and Altitude.

In Figure 2.2.3.2.1.1-B, the TCP's latitude and longitude are known, but its altitude is left unspecified. The TCR that describes this TCP will include values for the parameters Lat_TCP and Lon_TCP, but not for Alt_TCP. Equipment on board the transmitting aircraft will know that it has reached the TCP when the own-ship latitude and longitude are sufficiently close to the specified Lat_TCP and Lon_TCP values.

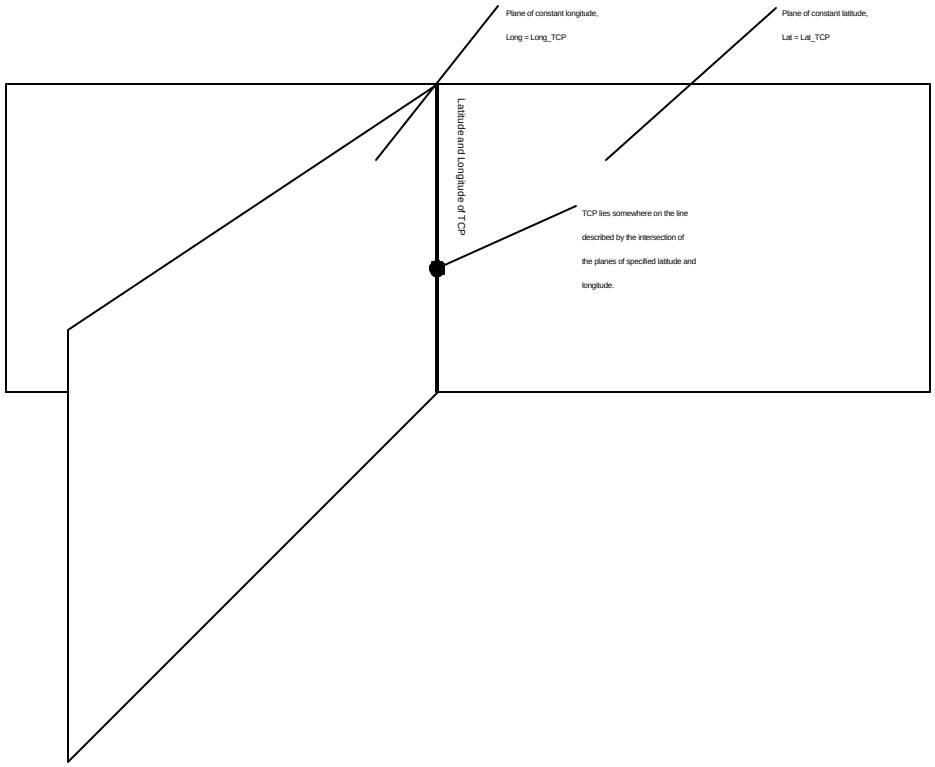

Figure 2.2.3.2.1.1-B: TCP Defined by Latitude and Longitude.

Another way that a TCP might be described in a TCR is as the intersection of the current aircraft's trajectory (as defined in the SV report) with a plane along which the aircraft would fly when approaching a subsequent TCP by flying a specified course. That is, the current trajectory change point (TCP+0) might be the point where the aircraft's trajectory will change so as to approach the TCP+1 by flying along a specified course. (The TCP+1 would be a "CF" or "Course to Fix" waypoint). Figure 2.2.3.2.1.1-C illustrates this. In this case, the TCR would describe the current TCP (TCP + 0) in terms of the latitude and longitude, not of the TCP, but of the TCP+1, together with the course angle along which aircraft is to approach the TCP+1.

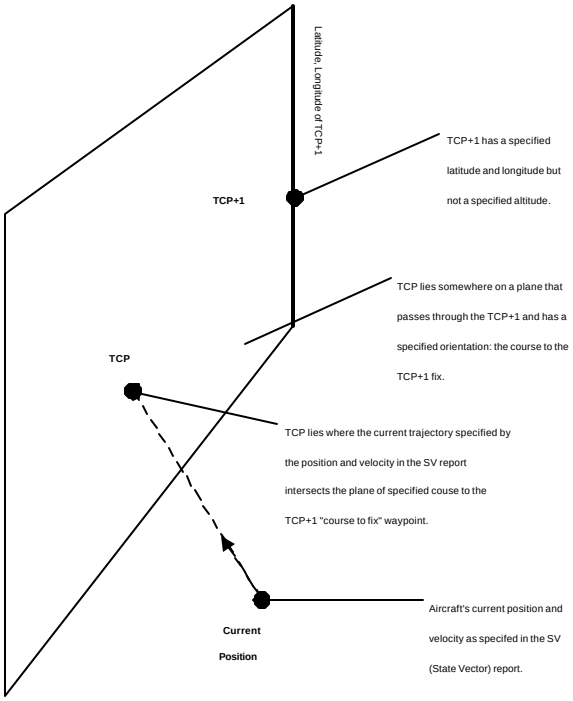

Figure 2.2.3.2.1.1-C: TCP Defined by SV and Course to Fix Waypoint.

2.2.3.2.1.2 TCR Elements

A Trajectory Change Report (TCR) contains elements that what is known about a particular TCP's location, together other parameters. The parameters that are required in the TCR that describes a particular TCP are:

- The TCP Type – Horizontal and TCP Type – Vertical. These TCR elements tell how the horizontal and vertical position elements of the TCR are to be interpreted.
- The Time To Go (TTG) until the aircraft reaches the TCP. This element is required so that the various TCPs that are currently defined can be placed in a time sequence: TCP, TCP+1, TCP+2, TCP+3.
- Command/Planned Flags for the horizontal and vertical elements of the TCR. (See section ??? below.)
- Data Available Flags for the horizontal and vertical elements of the TCR. (See section ??? below.)

The parameters that describe the TCP location might be:

~~, and estimated remaining flight time to that point. A TCP transmission indicates that the aircraft intends to fly directly, via a great circle route, to that point. The TCP is defined as a four-element vector consisting of the following:~~

- Latitude of TCP (WGS-84), if known
- Longitude of TCP (WGS-84), if known
- Altitude of TCP, if known

Other parameters describing a TCP that may be included in the TCR for that TCP are:~~(pressure altitude or flight level)~~

~~Time to go (TTG) to the indicated point in space~~

- The course or track angle that the aircraft will follow when approaching the the TCP
- The course or track angle that the aircraft will follow when departing from the TCP
- The radius of the turn that the aircraft will make on approaching or departing from the TCP.

The ~~TCP~~ TCR required received update rate may be lower than for the state vector. The rate shall (R2.33) be sufficient to ensure continuous positive assessment by the receiving aircraft at least 2 minutes (5 minutes within the range limitations specified in Table 2-3) prior to reaching closes point of approach for class A2 (A3) equipage. In the event of an immediate trajectory change generated via the RNav, new TCP information should be issued immediately.

The augmentation data should be provided as data transmitted indicating planned changes in trajectory. These indications should be provided as TCP information and TCP+1 information described below. ~~This data is required only from participants intending operations based on some level of cooperative conflict management.~~ The TCP and TCP+1 should be used to convey information operationally significant to separation and conflict management. Points constructed by RNav equipment to generate curvilinear paths (e.g., curved transitions between flight legs) should not be conveyed as TCP information.

System designs should be flexible enough to support parameters that might not be available from all ADS-B participating A/Vs. Information acquisition of intent information is provided in Appendix L.

~~Next Trajectory Change Point (TCP+1)~~

~~De-confliction is most efficient when adjustments to the flight path can be minimized. Knowledge of planned changes to the current path is needed to support the conflict management tools for stable operational re-planning required due to any conflict that may be predicted.~~

~~For the de-confliction capability, additional augmenting information should be provided to determine any change in horizontal and/or vertical flight path planned. The aircraft planning the change shall (R2.34) issue the TCP+1 information at least 5 minutes prior to commencing the trajectory change associated with the TCP. The TCP+1 data to be supplied should provide the target or predicted altitude, the target horizontal coordinates and the estimated time remaining from the time of generation of the message to the estimated time to arrive at TCP+1. Upon initiation of the flight path change at TCP, the TCP+1 should increment to become the new TCP. TCP+1 information shall (R2.35) be provided until commencing the change maneuver. The TCP+1 required transmission rate shall (R2.36) be the same as that of the TCP.~~

~~Notes:~~

~~TCP and TCP+1 data are provided by broadcast media to supply real time, event related data to proximate air and ground systems involved in advanced air operations requiring real time intent detail. Details of more complete flight plan or detailed procedures are conveyed, when required, via addressed datalink media.~~

~~No TCP is needed for speed changes along a trajectory. The data indicating the time to go for TCP and TCP+1 should include any results of planned or predicted changes. For RNav equipment capable of such predictions or scheduling, the time data should include the impacts. Less capable equipment should provide the best estimate available. Air or Ground systems receiving the TCP/TCP+1 data should be capable of applying these data as appropriate to their respective applications in conflict management, sequencing, spacing or conformance.~~

~~TCP and TCP+1 data are envisioned in current planning future procedures in the terminal area and transitions between en route flight regimes to enhance sequencing in arrival and departure. These data are intended for applications by both air and ground systems. The ADS-B system will enable the delivery of TCP and/or TCP+1 data when required by the procedures supported by the RNav onboard the transmitting participant. Receiving participants would use the transmitted capability codes to determine pair-wise compatibility with their respective applications.~~

~~For example, at shorter ranges, a pair of points (TCP and TCP+1) could be issued in conjunction with Terminal Maneuvering Area metering operations and/or when maneuvering to join or depart published procedures.~~

~~Lateral TCPs are fly-by points unless indicated to be fly-over. TCP and tCP+1 points are intended to convey trajectory target and trajectory change only. Accordingly, they are not necessarily RNav flight plan waypoints. They must be represented only in binary data form. Example TCPs are top of descent, reach climb altitude or intercept points used to capture procedures or join the flight plan.~~

~~Under some common operational sequences an aircraft may be manually departing or returning to an RNav flight plan. An example case would result from a period of vectored operation by ATS. In such cases the application should determine when to assume the intent is "direct to" or if the aircraft is operating with a different intent.~~

~~Other Information~~

~~System Performance – Standard Operational Conditions~~

~~ADS-B System definition and Functional Requirements~~

~~System Scope and Definition of Terms~~

~~ADS-B System Description~~

~~System Requirements~~

~~ADS-B Report Definitions~~

~~Report Assembly Design Considerations~~

~~Three report types are defined as ADS-B outputs to applications. They provide flexibility in meeting delivery and performance requirements for the information needed to support the operations identified in Section 2. Report types, also shown in Figure 3-8, are:~~

~~Surveillance State Vector Report (SV)~~

~~Mode/Status Report (MS)~~

~~On-Condition Report (OS)~~

~~All interactive participants must receive messages and assemble reports specified for the respective equipage class (Table 3.3(a)). All receive-only participants must receive messages and assemble reports as specified for the respective equipage class (Table 3-3(b)). All transmitting participants must output at least the minimum data for the SV and partial MS reports. The minimum requirements for exchanged information and report contents applicable for equipage classes are provided in Section 3.4.4.~~

~~ADS-B Message Exchange Technology Considerations in Report Assembly~~

~~Specific ADS-B Report Definitions~~

~~State Vector Report~~